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Acute Lethality of Copper, Cadmium, and Zinc to Northern Squawfish

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Acute Lethality of Copper, Cadmium, and Zinc to Northern Squawfish

JAMES D. ANDROS AND RONALD R. GARTON

United States Environmental Protection Agency, Corvallis Environmental Research Laboratory, Western Fish Toxicology Station, Corvallis, Oregon 97330

Abstract

Flow-through acute toxicity tests on juvenile northern squawfish (*Ptychocheilus oregonensis*) were conducted with copper, cadmium, and zinc. The 96-hour median lethal concentrations were 18 μg/liter for copper, 1,104 μg/liter for cadmium, and 3,693 μg/liter for zinc in 12 C water. These values, when compared to those for chinook salmon and steelhead parr tested under similar conditions, show that the northern squawfish are more tolerant than the two salmonids to zinc and cadmium but equally sensitive to copper.

The purpose of this research was to determine the effects of copper, cadmium, and zinc on the survival of juvenile northern squawfish (*Ptychocheilus oregonensis*, and to compare these survival rates to those of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Salmo gairdneri*) juveniles exposed to the same metals under similar conditions. The northern squawfish is known to compete for available food supplies with, and prey upon, salmonids (Ricker 1941; Brett and McConnell 1950; Jeppson and Platts 1959; Thompson 1959). In parts of the Pacific northwest the northern squawfish is increasing in range and numbers due, in part, to its environmental adaptability, to selective fishing for other species, and to accidental stocking by man (Jeppson and Platts 1959). The relative toxicities of copper, cadmium, and zinc to the different species may help determine if the northern squawfish has an advantage over salmonids which could provide opportunities to further increase squawfish range and abundance in waters containing these pollutants.

Methods

Two toxicity tests were run with each metal. The system used to distribute the metals was a continuous-flow toxicant delivery system as described by Garton (in press), which used six sets of duplicate aquaria receiving five concentrations of the metal and control water. Stock solutions were made from reagent-grade $CuCl_2 \cdot 2H_2O$, $CdCl \cdot 2.5H_2O$, or $ZnCl_2$, and acidified with 1 ml of concentrated HNO_3 per 10 liters of stock solution. This solution was then pumped into the mixing chamber of the diluter's delivery system.

The test chambers were glass aquaria with water volumes of approximately 31 liters each and 50% replacement times of 30 minutes as calculated from Sprague (1969). The grams of fish per liter of solution in the aquaria never exceeded 1.70 g/liter at any time nor did it exceed 0.05 g/liter/24 hours. These loading factors were well within recommended limits for flow-through toxicity tests (USEPA 1975). The number of fish per concentration varied, depending on the test, from 16 to 30. Occasionally 10 fish were used in the controls to conserve fish. There were no losses of control fish in any of the tests.

The northern squawfish were seined from the Willamette River near Corvallis, Oregon, during the summers of 1975 and 1976. During the course of the seining specimens of chiselmouth (*Acrocheilus alutaceus*) were also captured and concurrent tests were run with this species in copper to provide comparative data from another cyprinid. Fish were treated upon capture with Hyamine 1622[1] as a prophylactic treatment for external bacteria. During the time between capture and use in the tests it was occasionally necessary to treat the food, Oregon Moist Pellet, with Sulmet and Furox-50 to prevent outbreaks of disease (Wood 1974). Fish were not used until 14 days after treatment ended nor were they used if there were any

[1] Mention of brand names does not imply endorsement by the United States Environmental Protection Agency.

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TABLE 1.—*Calculated median lethal concentration (LC50) values and 95% confidence limits (in parentheses) for northern squawfish and chiselmouth exposed to different metals.*

Species	Metal	Net weight (g)	Fork length (cm)	LC50 (μg/liter)		Temperature
		Mean ± SD	Mean ± SD	96-hour	168-hour	Mean ± SD
Northern squawfish	Cadmium[a]	1.44 ± 0.42	5.6 ± 0.5	1,092 (923–1,275)	1,042 (791–1,398)	17.2 ± 0.5
Northern squawfish	Cadmium[b]	2.49 ± 0.80	6.0 ± 0.8	1,104 (752–1,598)	1,062 (581–1,369)	12.0 ± 0.6
Northern squawfish	Zinc[c]	6.58 ± 2.10	8.6 ± 1.1	3,498 (3,131–3,859)	2,948 (2,657–3,266)	9.5 ± 0.3
Northern squawfish	Zinc[d]	0.51 ± 0.25	3.7 ± 0.6	3,693 (3,329–4,210)	3,650 (3,367–4,006)	12.4 ± 0.2
Northern squawfish	Copper[e]	1.33 ± 0.83	5.0 ± 0.9	23 (9–26)	11 (4–12)	7.8 ± 0.3
Northern squawfish	Copper[f]	3.69 ± 1.41	7.2 ± 1.0	18 (15–22)	11 (9–14)	11.5 ± 0.0
Chiselmouth	Copper[g]	1.25 ± 0.37	4.6 ± 0.4	143 (115–291)		10.5 ± 0.4

[a] Mean concentrations (measured): 1,773; 1,239; 775; 561; 363 μg/liter.
[b] Mean concentrations (measured): 1,408; 1,062; 632; 429; 291 μg/liter.
[c] Mean concentrations (measured): 4,347; 3,549; 2,730; 2,085; 1,652 μg/liter.
[d] Mean concentrations (measured): 4,312; 3,932; 3,383; 2,920; 2,555 μg/liter.
[e] Mean concentrations (measured): 46; 26; 12; 6; 3 μg/liter.
[f] Mean concentrations (measured): 57; 30; 16; 9; 6 μg/liter.
[g] Mean concentrations (measured): 145; 112; 87; 69; 54 μg/liter.

mortalities within 48 hours prior to the start of a test. Food was withheld beginning 24 hours before fish were moved into the test aquaria. Fish were randomly distributed among aquaria and acclimated at test temperature for 72 hours prior to the start of the test. Fish were fed once during the first 24 hours of the 72-hour acclimation period, and 24 hours prior to the start of the test debris and feces were siphoned from the aquaria. Fish were considered dead when they ceased opercular ventilation and did not respond to touch. The means and standard deviations of the weights and fork lengths of the fish used in each test are given in Table 1.

Dissolved oxygen, pH, total alkalinity, and total hardness were usually determined daily during the testing period on water from one control aquarium and one aquarium receiving the toxicant. Methods were those recommended by APHA et al. (1971) and USEPA (1974). Dissolved oxygen ranged from 8.6 to 11.3 mg/liter; pH from 7.1 to 7.5. With two exceptions total alkalinity and total hardness fell in the range 20–30 mg/liter $CaCO_3$; during the tests of copper at 11.5 C with northern squawfish and at 10.5 C with chiselmouth total alkalinity was 42–44 mg/liter and total hardness 52–56 mg/liter, which was attributable to occasional increases in these variables due to rainfall during the winter months. Water temperature on all tests but one was monitored continuously by thermograph charts. The exception was the copper test at 11.5 C where temperature was taken with a manual thermometer. When testing temperature was different from that at which the fish were being held, the fish were acclimated at the rate of 1 C per day until the test temperature was reached. The temperature of the test water was never more than 3 C different than the holding water temperature.

The water used in the tests was supplied by wells at the Western Fish Toxicology Station and is described in detail by Samuelson (1976). The mean background concentration, based on weekly samples, in Station well water is 0.003 mg/liter copper, less than 0.001 mg/liter cadmium, and 0.005 mg/liter zinc. Copper and cadmium concentrations were determined by flameless atomic absorption on a Perkin-Elmer model 305B spectrophotometer equipped with an HGA 2000 heated graphite atomizer. Zinc analysis was done by flame atomic absorption with a Perkin-Elmer model 403 spectrophotometer. Generally, samples were taken daily from an aquarium for each of five metal concentrations and a control. Samples for metal analysis were taken in acid-washed, sample-rinsed containers, and the samples were routinely acidified by the addition of 1 volume-percent of reagent grade, concentrated HNO_3. The observed metal concentrations averaged 94% of nominal values with a standard deviation of 7%.

Statistical analysis of the data was performed by computer program maintained on a CDC 3300 computer which fits a logistic regression function to the data by the method of maximum likelihood (Finney 1971). The analysis

provides the median lethal concentration (LC50) and its 95% confidence limits.

Results and Discussion

The 96-hour and 168-hour LC50 values and their 95% confidence limits are given in Table 1. The values are quite close to those reported in the literature for another member of the Cyprinidae; Pickering and Henderson (1966), conducting static bioassays in soft water (20 mg/liter) with fathead minnows (*Pimephales promelas*), determined average LC50 values of 23 μg/liter of copper at 25 C, 1,340 μg/liter of cadmium at 25 C, and 2,550 μg/liter of zinc at 15 C. Mount and Stephan (1969), using flow-through toxicity tests and fathead minnows, obtained an LC50 of 75 μg/liter of copper at 25 C at a hardness of 31.4. In the tests we conducted with copper under the same test conditions, chiselmouths appeared to be more resistant than northern squawfish (Table 1).

Chapman (1978) reported the results of salmonid tests similar to ours, having used the same dilution water and analytical methods reported here. His tests were conducted at 12 C, at a hardness of 23 mg/liter $CaCO_3$, and with similar experimental design and analysis. For chinook salmon parr he found 96-hour LC50 values of 3.5 μg/liter for cadmium, 38 μg/liter for copper, and 463 μg/liter for zinc. For steelhead parr Chapman reported 96-hour LC50 values of 1.0 μg/liter cadmium, 18 μg/liter copper, and 136 μg/liter zinc. Our 96-hour LC50 values for northern squawfish were 1,104 μg/liter cadmium at 12 C, 18 μg/liter copper at 10.5 C, and 3,693 μg/liter zinc at 12.4 C.

The extreme differences in cadmium toxicity between northern squawfish and steelhead led us to conduct another test which was a joint bioassay with these two species exposed to cadmium. The test had three aquaria at each of five concentrations and three control aquaria. At each concentration and in the controls, one aquarium had steelhead only, one had northern squawfish only, and one had steelhead and northern squawfish together. The concentrations selected were designed to bracket the LC50 for steelhead and the LC50 for northern squawfish. These data were not used to calculate point estimates of the LC50 but they did confirm the relative difference in sensitivities. Northern squawfish maintained 100% survival for 96 hours at concentrations as high as 992 μg/liter while steelhead survival was reduced to 10 and 20% in two successive tests at 1.7 μg/liter.

Our results show that juvenile northern squawfish can survive much higher concentrations of cadmium and zinc than the juvenile salmonids with which they often compete for food and upon which they may prey as adults. This is only one of the factors which may limit numbers or distribution of a species but relative sensitivity to cadmium and zinc may give the northern squawfish a competitive advantage in northwestern streams with significant levels of metal contamination. This concept will have to be tested with actual field research on the distributions of the competing species.

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